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Contribution to the taxonomy of *Bovista* in Mexico

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Abstract — Specimens of the genus *Bovista* from eight Mexican herbaria (CESUES, ENCB, FCME, HEMIM, IBUG, IZTA, MEXU, XAL) were examined and studied, and fifteen taxa were identified: *Bovista aestivalis, B. brunnea, B. dermoxantha, B. dominicensis, B. fusca, B. grandipora, B. graveolens, B. heterocapilla, B. leucoderma, B. oblongispora* var. *longispora*, *B. oblongispora* var. *oblongispora, B. plumbea, B. pusilla, B. sempervirentium,* and *B. tomentosa*. The new information obtained indicates a wider distribution for *B. aestivalis, B. dermoxantha, B. fusca, B. graveolens, B. leucoderma, B. oblongispora* var. *longispora, B. pusilla,* and *B. tomentosa*. New records for the Mexican mycobiota are: *B. dominicensis, B. grandipora, B. heterocapilla, B. oblongispora* var. *oblongispora,* and *B. sempervirentium*.

Key words — *Basidiomycota,* taxonomy, gasteroid fungi

Introduction

The genus *Bovista* Pers. is characterized by globose to pyriform basidiomes with/without a short pseudostipe and with/without mycelial cords (Pegler et al. 1995) and a thin, fragile, scaly exoperidium. On maturing the basidiome may form plates, areolae, verrucae, or scales microscopically composed of hyphal elements, sphaerocysts, claviform cells (Kreisel 1967), or mycosclereids (Calonge et al. 2005). The endoperidium is persistent, in consistency papyraceous, pseudopapyraceous, or rigid, smooth and generally shiny or with a metallic luster (Coker & Couch 1928), although this does not distinguish *Bovista* from other related genera. According to Smith (1951), spores are

smooth or ornamented. Shape varies, from globose, subglobose to oblong, with a pedicel, which may be short or long, straight or curved, corresponding to the sterigma of the basidium. The subgleba, present only in some species, has a filamentous, compact appearance and is generally reduced in size and not well developed. There are three types of capillitium: *Lycoperdon*, *Bovista,* and intermediate (Calonge 1998; Krüger et al. 2001).

Bovista, traditionally placed in *Lycoperdaceae* but currently classified in *Agaricaceae* (Kirk et al. 2008), is divided into two subgenera based on capillitial type. Taxa characterized by a *Lycoperdon* or intermediate capillitium are placed in subg. *Globaria*, while those with either a *Bovista* or heteromorphic (*bovista*- + intermediate) capillitium belong in subg. *Bovista*. These subgenera are further divided into sections and series based on capillitium type, absence or presence of capillitial pores, and presence or absence of a subgleba (Kreisel 1967).

In Mexico few researchers have addressed the taxonomy of *Bovista* (Herrera 1959); the genus is generally included in general gasteromycete treatments (Salcedo & Herrera 1966, Guzmán & Herrera 1969, 1973, Rodríguez & Herrera 1970, Urista et al. 1985, Esqueda et al. 1990, 1996, 1998, Pardavé 1991, Pérez-Silva et al. 1994, Calonge et al. 2004a,b, Ochoa & Moreno 1996, 2006). *Bovista* has been confused with *Lycoperdon* Pers., *Disciseda* Czern., *Calvatia* Fr., *Vascellum* F. Šmarda, *Bovistella* Morgan, and *Calbovista* Morse ex M.T. Seidl, owing to shared macro- and microscopic characteristics. There are, however, differences that allow them to be quite easily separated. Confusion surrounding the correct identification of species has prompted this revision of *Bovista* with the aim of contributing to the knowledge of the genus in Mexico.

Materials & methods

Herbarium material was examined from CESUES (Centro de Estudios Superiores del Estado de Sonora, Unidad Hermosillo), ENCB (Escuela Nacional de Ciencias Biológicas, IPN), FCME (Facultad de Ciencias, UNAM), HEMIM (Herbario Micológico de Morelos, UAEM), IBUG (Instituto de Botánica, Universidad de Guadalajara), IZTA (Facultad de Estudios Superiores campus Iztacala, UNAM), MEXU (Instituto de Biología, UNAM), and XAL (Instituto de Ecología, A.C., Unidad Xalapa).

Macroscopic characters were transcribed from specimen labels or recorded directly from the basidiomes. For microscopic examination, temporary preparations were made using 5% potassium hydroxide (KOH) for observing and measuring basidiospores and capillitial elements with an optical microscope (OM). Lactophenol cotton blue was used for observing the paracapillitium. Material was also prepared for observation using a scanning electron microscope (SEM) in order to properly describe spore ornamentation and perforations in the hyphal walls of the capillitium.

The keys of Kreisel (1967), Demoulin & Marriot (1981), Calonge (1992, 1998) and Pegler et al. (1995) were mainly used for species identification.

Results

Of the 15 *Bovista* taxa identified and included in the taxonomic key, 9 represented subgenus *Globaria* (*B. aestivalis*, *B. dermoxantha*, *B. dominicensis*, *B. grandipora*, *B. heterocapilla*, *B. oblongispora* var. *longispora*, *B. oblongispora* var. *oblongispora*, *B. pusilla, B. sempervirentium*) and 6 subgenus *Bovista* (*B. brunnea*, *B. fusca*, *B. graveolens*, *B. leucoderma*, *B. plumbea, B. tomentosa*). Five taxa are new records for the Mexican mycobiota and are described below: *B. dominicensis*, *B. grandipora*, *B. heterocapilla*, *B. oblongispora* var. *oblongispora,* and *B. sempervirentium*.

Key to the taxa of Bovista recorded from Mexico

1. Basidiomes with intermediate or *Lycoperdon* capillitium 2
1'. Basidiomes with *Bovista* type capillitium 11

2. Intermediate type capillitium 3
2'. *Lycoperdon* type capillitium 7

3. Basidiomes with ellipsoid spores, short pedicels 4
3'. Basidiomes with globose spores 5

4. Capillitium with pores ..... *B. oblongispora* var. *longispora*
4'. Capillitium pores absent ..... *B. oblongispora* var. *oblongispora*

5. Heteromorphic capillitium 6
5' Intermediate capillitium 7

6. Spores with pedicels ≤ 11 μm ..... *B. pusilla*
6'. Spores with pedicels ≤ 17 μm ..... *B. heterocapilla*

7. Echinulate spores with pedicels ≤ 34 μm ..... *B. dominicensis*
7'. Spores with small verrucae 8

8. Capillitium with branches 9
8'. Capillitium without branches 10

9. Capillitium with amphiseptal branches, numerous pores, giving a vacuolate appearance..... *B. grandipora*
9'. Capillitium with subseptal branches, with pores ..... *B. dermoxantha*

10. Exoperidium verrucae made of sphaerocysts ..... *B. aestivalis*
10' Exoperidium verrucae made of hyphal elements ..... *B. sempervirentium*

11. Basidiomes medium to large, > 55 mm 12
11' Basidiomes small to medium, ≤ 55 mm 13

12. Spores subglobose to ovoid, pedicels straight ..... *B. fusca*
12'. Spores globose to subglobose, pedicels curved..... *B. graveolens*

13. Capillitium with pores 14
13'. Capillitium pores absent, endoperidium lead colored ..... *B. plumbea*

14. Spores ovoid. . . . . *B. tomentosa*
14'. Spores globose to subglobose 15
15. Capillitium with thick walls, LH = 0.2–0.5 . . . . . *B. brunnea*
15'. Capillitium with moderately thin walls, LH = 0.5–0.7 . . . . . *B. leucoderma*

Taxa studied

Subgenus *Globaria*

Bovista aestivalis (Bonord.) Demoulin, Beih. Sydowia 8: 143, 1979. Figs 1–2

Specimens examined: **MÉXICO. Hidalgo:** Mineral del Chico Municipality, near Las Ventanas, El Chico National Park, October 5, 1980 *G. Guzmán 19099* (ENCB). **Jalisco:** San Diego de Alejandría Municipality, San Diego de Alejandría-San Julián Highway, 7.5 km from the town of San Diego de Alejandría, August 30, 2000 *O. Rodríguez 2332* (IBUG). **Estado de México:** Near Amecameca, August 31, 1969 *I. Uribe 11* (ENCB); Near La Marquesa, Miguel Hidalgo National Park, July 5, 1963 *E. González 12* (ENCB); Atizapan de Zaragoza Municipality, Sayavedra Farm subdivision, June 18, 2000 *A. López-Villalobos 24* (XAL). **Oaxaca:** San Pedro Macuiltianguis, June 15, 1984 *A. González* (XAL).

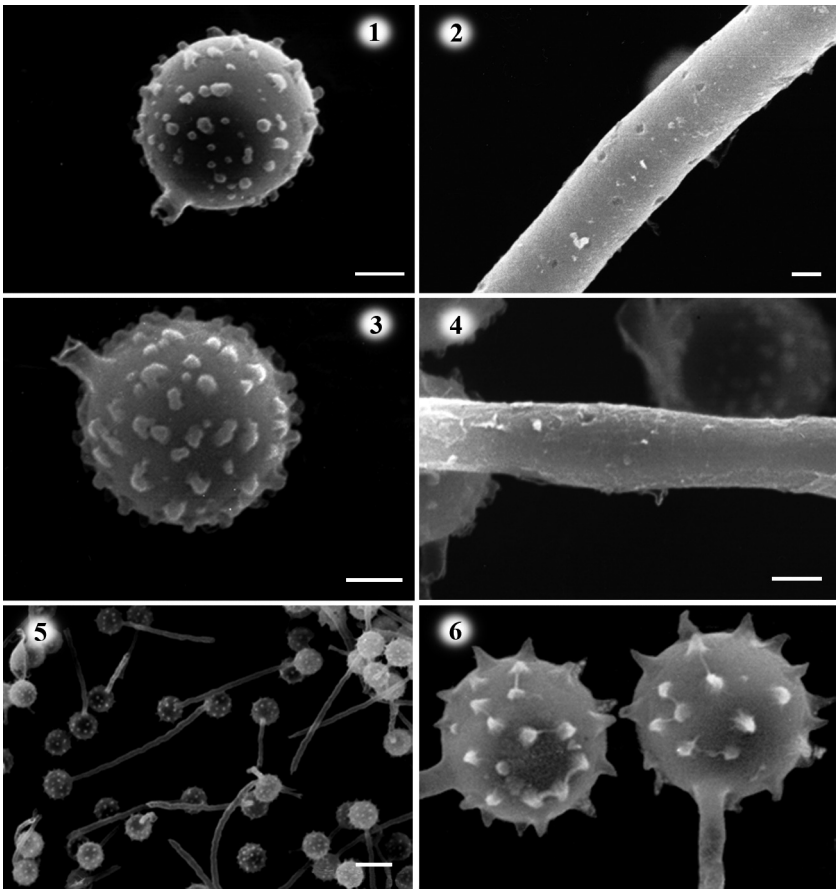
Comments — This species is characterized by a compact subgleba, evident or barely developed. Unlike *Bovista dermoxantha, B. aestivalis* has an intermediate type of capillitium and under the OM the spores show an ornamentation that is not very evident. Pegler et al. (1995) mention that it is a very polymorphic species and thus taxonomically difficult to identify.

Bovista aestivalis has been cited for Baja California (Ochoa & Moreno 2006), Chihuahua (Moreno et al. 2010), Estado de México, Oaxaca and Veracruz (Calonge et al. 2004b). This study extends its distribution range to the states of Hidalgo and Jalisco.

Bovista dermoxantha (Vittad.) De Toni, Syll. Fung. 7: 100, 1888. Figs 3–4

Specimens examined: **MÉXICO. Baja California:** km 2, close to the turnoff from Ensenada to the San Felipe highway, on the way to Hanson Lagoon, in the foothills of the Juárez range, March 02, 1984 *G. Guzmán 24326-A* (XAL). **Chihuahua:** Temósachi Municipality, Nabogame, July 31, 1987 *J. E. Laferrière 624* (XAL); 65 km NW of Janus, September 20, 1972 *P. Huerta* (ENCB). **Hidalgo:** San Gregorio, north side of Xihuingo Hill, July 26, 1963 *G. Guzmán 3865* (ENCB). **Estado de México:** Close to the Guadalupe Dam, July 02, 1967 *G. Guzmán 5862* (ENCB). **Sonora:** km 12 on the Santa Rosa-Yécora highway, August 6, 1989 *A. Aparicio 4* (MEXU 22589). **Tlaxcala:** Huamantla Municipality, 2 km south of La Malinche mountain, July 19, 1987 *Mata 217* (XAL). **Veracruz:** Montepío, June 19, 1969 *R. Singer* & *T. Herrera* (MEXU 6897); Iztaczoquitlán Municipality, in the region of Metlac Gorge, August 09, 1995 *P. Navarro 1042*; September 13, 1996 *P. Navarro 1095* (XAL).

Comments — Pegler et al. (1995) mention that this species is close to *B. aestivalis* but differs by its conspicuously ornamented spores and the *Lycoperdon* type capillitium.



Figs. 1–6. *Bovista aestivalis*: 1. Spores. 2. Pitted capillitium. *Bovista dermoxantha*: 3. Spores. 4. Pitted capillitium. *Bovista dominicensis*: 5. Spores. 6. Spores ornamentation detail. Scale bars: 1–4, 6 = 1 μm; 5 = 5 μm.

Bovista dermoxantha has been reported for the states of Baja California (Calonge et al. 2004b; Ochoa & Moreno 2006), Chihuahua, Tlaxcala and Veracruz (Calonge et al. 2004b). This study extends its distribution range to Hidalgo, Estado de México and Sonora.

Bovista dominicensis (Massee) Kreisel, Feddes Repert. 69: 202, 1964. Figs 5–6

Basidiome 12–37 mm, globose to flattened-globose, exoperidium forms small pyramidal scales like spines, blackish-brown to greyish in color, formed by sphaerocysts that are reddish-brown in KOH; endoperidium whitish, of intertwined hyaline hyphae. Gleba white to olive green. Subgleba compact.

Lycoperdon type capillitium, hyphae thin walled, 4–5 μm, light brown in color, pores absent, barely branched, septa scarce. Paracapillitium absent. Spores globose, 4–5 μm, equinulate, hyaline. Pedicel 13–30(–34) × 1 μm, straight, hyaline.

Ecology & distribution — Gregarious, humicolous in cloud forests, *Pinus–Quercus* in transition with cloud forest and tropical vegetation with columnar cacti, at an altitude of 1270–1550 m.

Specimens examined: **MÉXICO. Puebla:** La Magdalena Farm, S of Teziutlán, October 14, 2004 *E. Gándara 1161*. **Sinaloa:** El Fuerte road to stones with hieroglyphics, after the El Fuerte River, August 24, 2004 *G. Guzmán 36091*. **Veracruz:** Surroundings of the CONECALLI-DIF social services building, km 2.5 Xalapa-Coatepec Old Highway, September 7, 1993 *D. Fernández 38*; Xico Municipality, road from Xico to Matlalapa, before arriving at Xico Viejo, September 3, 2000 *D. Jarvio 677*; Banderilla Municipality, La Martinica Hill, July 01, 2004 *V. Ramírez-Cruz 94*; La Martinica Hill, August 21, 2006 *G. Guzmán 36569*; Coatepec Municipality, Zoncuantla, royal road from Xalapa to Coatepec near km 6 of the Xalapa-Coatepec Old Highway (residence), September 18, 1998 *G. Guzmán 32468*; September 20, 1998 *G. Guzmán 32482*; September 29, 1998 *G. Guzmán 32666*; December 30, 1998 *G. Guzmán 32771*; June 24, 1999 *G. Guzmán 32995*; June 27, 1999 *G. Guzmán 33022*; June 01, 2000 *G. Guzmán 33495*; July 13, 2003 *G. Guzmán 35488*; October 03, 2003 *G. Guzmán 35568*; November 02, 2003 *G. Guzmán 35704*; October 02, 2004 *G. Guzmán 36119*; *G. Guzmán 36122*; October 05, 2004 *G. Guzmán 36125*; *G. Guzmán 36127*; October 07, 2004 *G. Guzmán 36133*; *G. Guzmán 36277*; July 10, 2005 *G. Guzmán 36228*; July 26, 2005 *G. Guzmán 36311*; *G. Guzmán 36328*; October 23, 2005 *G. Guzmán 36367*; July 02, 2006 *G. Guzmán 36440*; September 15, 2006 *G. Guzmán 36678*; Xalapa Municipality, F.J. Clavijero Botanical Garden, km 2.5 on the Old Highway to Coatepec, June 03, 1995 *García-Velázquez 779*; July 03, 1995 *García-Velázquez 780*; July 10, 2003 *F. Escalona 196*; September 30, 2004 *E. Gándara 892*; October 07, 2004 *E. Gándara 932*; *V. Ramírez-Cruz 189* (XAL).

Comments — *Bovista dominicensis*, is characterized microscopically by globose and echinulate spores with long pedicels from 13 up to 34 μm. Macroscopically it can be confused with *Lycoperdon* because the basidiome is pyriform owing to the presence of a pseudostipe.

Part of the material examined had been identified as *B. longissima* Kreisel and thus reported as a new record for the Americas (Calonge et al. 2004b). However, *B. longissima* has verrucose spores and pedicels ≤ 38 μm long and to date it has been recorded only from Japan (Kreisel 1967). Spore ornamentation places it in *B. dominicensis*, as it is the same as that in the SEM images shown in the study by Calonge et al. (2005). Although those authors describe the spores as verrucose, Kreisel (1967) described them with fine verrucae to delicate spines. The pedicels of the examined specimens were longer (≤ 34 μm) than those reported by Kreisel (10–21 μm) and Calonge et al. (20 μm).

Worldwide, *B. dominicensis* has been reported for Brazil (Kreisel 1967, Homrich 1969 [as *Lycoperdon dominicensis*], Trierveiler et al. 2010), the United States of America, the Dominican Republic (Kreisel 1967), Colombia (Guzmán

et al. 2004), and Costa Rica (Calonge et al. 2005). This is the first report of *B. dominicensis* for Mexico, where it has been recorded from the states of Puebla, Sinaloa and Veracruz.

Bovista grandipora Trierv.-Per., Kreisel & Baseia, Mycotaxon 111: 415, 2010. Figs 7–8

Basidiome 10–12 mm in diameter, globose. Exoperidium white, breaking into small scales, furfuraceous in appearance, made up of short fragments of hyphae, orange-red color in KOH. Endoperidium greyish brown to dark brown. Gleba white to mustard yellow. Subgleba absent. Mycelial cord radicant.

Lycoperdon type capillitium, with amphiseptal septa, pores abundant, giving a vacuolate appearance. Globose spores, 4–5 µm, verruculose, greenish-yellow. Short pedicel, 0.5–1 µm, hyaline.

Ecology & distribution —Terricolous, gregarious in the grass. Found in open *Juniperus deppeana* forest and in tropical vegetation at altitudes of 2500 and 1500 m, respectively.

Specimens examined: **MÉXICO. Jalisco:** San Pedro Tesistán Municipality, highway to Azuayo, W side of the Chapala Lagoon, July 07, 1974 *G. Guzmán 11582-B* (ENCB); Zapopan Municipality, 2 km NW of La Venta, September 27, 1970 *D. García 452* (IBUG). **Puebla:** Santa Cruz, between San Martín Texmelucan and La Blanca, August 25, 1956 *T. Herrera* (MEXU 901).

Comments — The specimens examined coincide with the description of *Bovista grandipora* given by Trierveiler-Pereira et al. (2010), Microscopically, *B. grandipora* is characterized by a capillitium of the *Lycoperdon*-type with numerous pores, 0.5–2.4 µm, round to ellipsoid or irregularly shaped, and globose, verruculose with short pedicel (0.5–1 µm) basidiospores.

Worldwide, this species has been recorded for Brazil, Cuba, Dominican Republic, India, Japan, Nepal, Puerto Rico and Spain (Trierveiler-Pereira et al. 2010). This is its first record for Mexico, specifically for the states of Jalisco and Puebla.

Bovista heterocapilla Kreisel, Beih. Nova Hedwigia 25: 224, 1967. Figs 9–11

Basidiome globose, subglobose to turbinate. Endoperidium papyraceous, smooth, brown in color, made of intertwined hyphae. Exoperidium is white, ephemeral, persistent small spines (spinulose), blackish-brown, made up of sphaerocysts. Subgleba absent or if present, compact, olive brown to dark brown.

Bovista type or heteromorphic capillitium in the center of the gleba, hyphae with pseudosepta frequent, true septa and pores absent. Spores 5–6 µm, verrucose, pedicellate. Pedicel 8–17 µm, straight, hyaline.

Ecology & distribution — Gregarious, terricolous in *Abies, Abies-Quercus* and cloud forest at an altitude of 2330 to 2800 m.

Specimens examined: **MÉXICO. Distrito Federal:** Contreras, Cerro Tarumba, October 21, 1956 *T. Herrera* (MEXU 1426). **Hidalgo:** El Chico National Park, Las Ventanas, September, 1970 *R. Ramos 105* (ENCB); El Chico National Park, October 25, 1975 *R. Hernández* (MEXU 12871); Piedras Voladas, Real del Monte, June 13, 1982 *E. Pérez*-Silva & *R. Hernández* (MEXU 17283); Pueblo Nuevo, October 08, 1975 *E. Pérez-Silva* (MEXU 11312). **Estado de México:** Amecameca, September 18, 1963 *A. Nájera* (MEXU 2761); La Marquesa-Tenango Highway km 6, October 05, 1975 *R. Lamothe* & *E. Pérez-Silva* (MEXU 10163); La Marquesa, October 21, 1973 *R. Lamothe* & *E. Pérez-Silva* (MEXU 8442); Purificación NE of Texcoco, September 05, 1976 *G. Guzmán 16477* (ENCB).

Comments — This species is characterized by a *Bovista* type capillitium; heteromorphic in some specimens, i.e., of the intermediate+*Bovista* type. Although Kreisel (1967) mentions that it has the *Lycoperdon* type of capillitium, the characteristics of the hyphae and the spores match those cited for *B. heterocapilla*.

One species close to *B. heterocapilla* is *B. albosquamosa* Kreisel. These are distinguished by the characteristics of the exoperidium and the spore ornamentation. In *B. heterocapilla* the exoperidium is uniformly granular-verrucose and the spores are verrucose, while in *B. albosquamosa* the exoperidium is furfuraceous areolate and the spores are dotted or verruculose (Kreisel 1967).

Bovista heterocapilla has been reported only for Jamaica (Kreisel, 1967). This is the first record for Mexico.

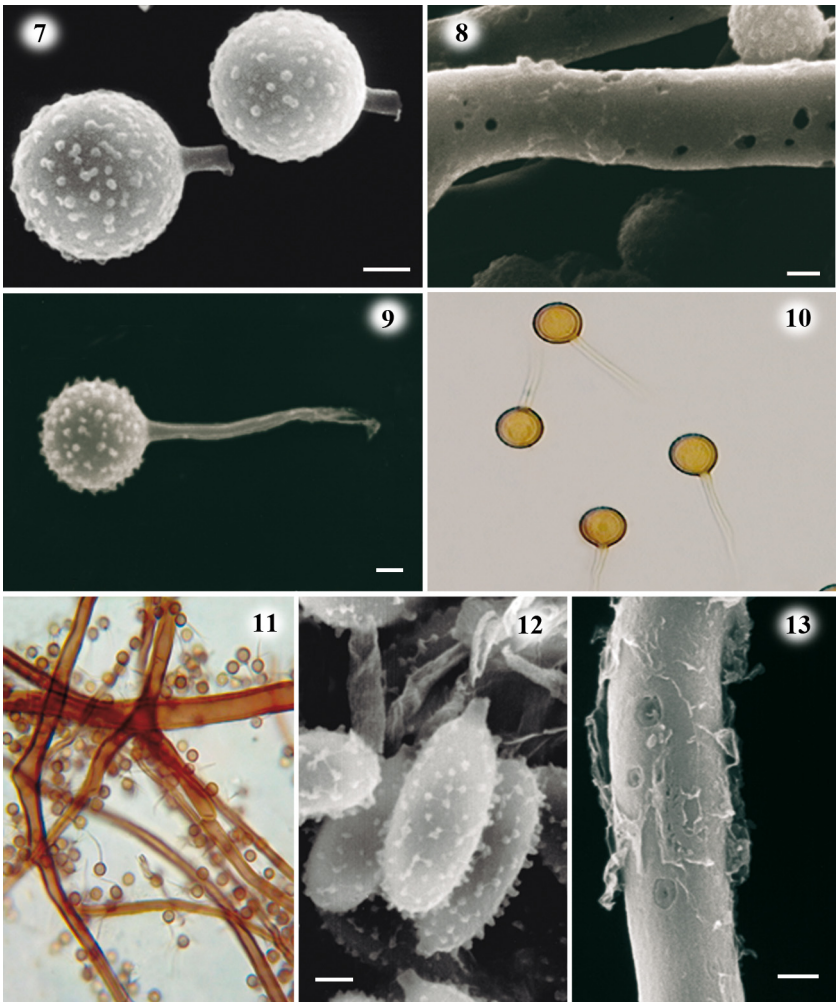
Bovista oblongispora var. ***longispora*** (Kreisel) A. Ortega & Buendía, Cryptogamie, Mycol. 6: 285, 1985. Figs 12–13

Basidiome 13–20 × 10–15 µm, subglobose to slightly pyriform; when young, the exoperidium is reddish in color, later it disintegrates, leaving reddish-brown scaly remains, exposing an ochraceous endoperidium, shiny and papyraceous in consistency. Gleba whitish, yellowish to dark chocolate brown, fleshy-alveolate to powdery in consistency. Subgleba present.

Intermediate type capillitium, hyphae 4–5(–6) µm, pores moderately frequent, wall thin, septate, with dichotomous branching. Paracapillitium absent. Spores 5–7 × 3–4 µm, ellipsoid to cylindrical, verrucose; verrucae irregularly distributed. Pedicel 1–2.5 µm, occasionally up to 8 µm.

Ecology & distribution — Gregarious, terricolous in *Quercus–Pinus* forest, cloud forest, pastures and coffee plantations at altitudes of 1250–2300 m.

Specimens examined: **MÉXICO. Puebla:** Close to the Ocochiguaya Gorge, E side of Chignahuapan, July 12, 1975 *Herrera, Hernández, Cruz* & *Guzmán* (MEXU 25336). **Sonora:** Yécora Municipality, km 3.4 along the Yécora- Las Cabañas road, September 12, 1996 *M. Esqueda, A. Armenta, A. Núñez* & *R. Santos* (CESUES 3181); September 13, 1996 (CESUES 3013); Ónavas Municipality, km 204.5 on the Hermosillo-Yécora road, October 06, 1995 *E. Pérez, T. Herrera, M. Esqueda, A. Armenta, A. Núñez, R. Rodríguez* & *R. Santos* (CESUES 2107). **Veracruz:** Highway to Fortín, 10 km from



Figs. 7–13. *Bovista grandipora*: 7. Spores. 8. Pitted capillitium. *Bovista heterocapilla*: 9. Spore under SEM. 10. Spores under OM ×1600. 11. Capillitium and spores under OM ×400. *Bovista oblongispora* var. *longispora*: 12. Spores. 13. Pitted capillitium. Scale bars = 1 µm.

Huatusco, July 20, 1983 *S. Chacón 1189* (XAL); highway to Fortín, Tepampa turnoff, 10 km from Huatusco, July 27, 1983 *G. Guzmán 23527* (XAL); Coatepec Municipality, Zoncuantla, close to the road to Coatepec, August 15, 1994 *G. Guzmán 30930* (XAL).

Comments — For the identification of this species the criteria of Ortega & Buendía (1985) were applied. They propose that *B. longispora* and *B. oblongispora*

are varieties of a single species. They argue that the difference between the two lies in the respective presence or absence of pores in the capillitium.

In his monograph, Kreisel (1967) treats the two taxa as separate species, stating that *B. longispora* has a *Lycoperdon* type capillitium with pores and compact subgleba, while *B. oblongispora* has an intermediate type capillitium, no pores, and no subgleba.

Bovista oblongispora var. *longispora* has previously been reported from Mexico as *B. longispora* (Calonge et al. 2004b; Esqueda et al. 1996; 1998 and Pérez-Silva et al. 1994).

Bovista oblongispora (Lloyd) Bottomley, Bothalia 4(3): 580, 1948
var. ***oblongispora*** Figs 14–15

Basidiome globose to subglobose 17–18 mm in diameter. Exoperidium formed by small needles separated by approximately 0.5 mm, comprised of hyphae and sphaerocysts; endoperidium brown in color to dark chocolate brown, membranous. Gleba powdery, yellowish-brown to dark brown in color. Subgleba yellowish-brown, compact.

Intermediate type capillitium, hyphae 6–7(–8) µm, pores absent, wall thin, dichotomous branching. Paracapillitium absent. Basidiospores 5–7 × 2.5–3 µm, oblong to ellipsoid, verrucose, with a regular longitudinal arrangement. Pedicel 0.5 µm, hyaline.

Ecology & distribution — Solitary, terricolous in cloud forest at an altitude of 1300 m.

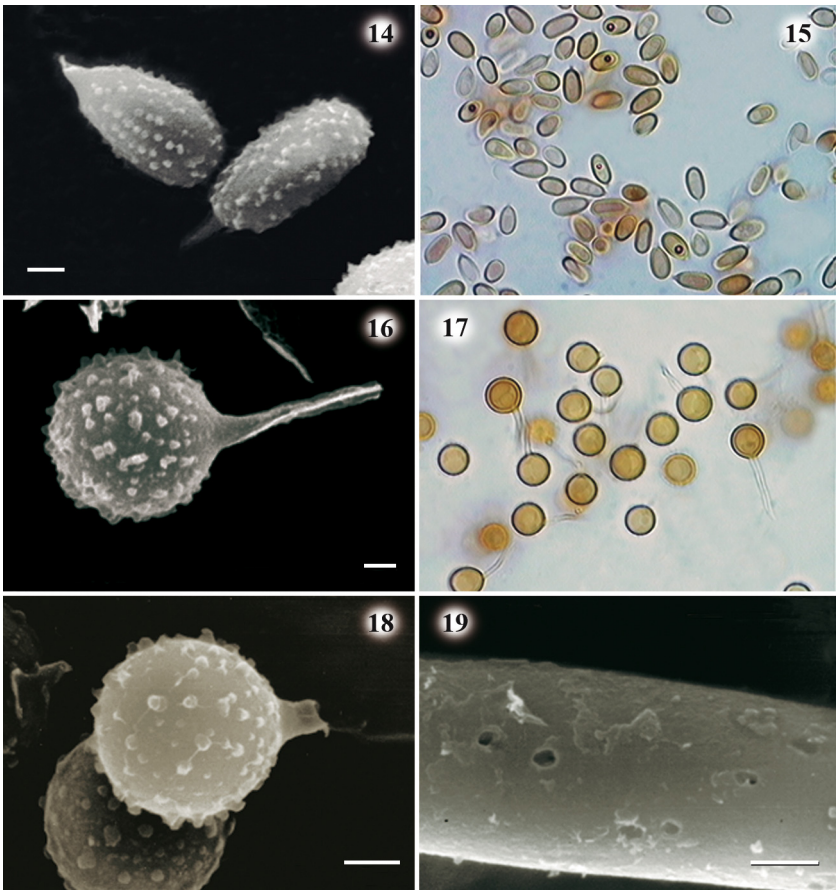
Specimen examined: **MÉXICO. Veracruz:** Xalapa Municipality, km 2.5 on the Xalapa-Coatepec Old Highway, Francisco Javier Clavijero Botanical Garden, May 14, 2005 *Gándara 1268* (XAL).

Comments — This variety can be distinguished from *B. oblongispora* var. *longispora* by the absence of pores and the generally predominant ellipsoid shape of the spores. This is the first record for Mexico.

Bovista pusilla (Batsch) Pers., Syn. Meth. Fung. 1: 138, 1801. Figs 16–17

Specimens examined: **MÉXICO. Jalisco:** Zapotlán El Grande Municipality, the foothills of Nevado de Colima, Las Víboras track, Floripondio, June 27, 1999 *Montoya-Fuentes 14* (IBUG). **Estado de México:** La Marquesa, October 18, 1976 *A. González* (FCME 496); Naucalpan Municipality, Los Remedios, October 7, 1956 *T. Herrera* & *O. Sánchez* (MEXU 1416). **Sonora:** Yécora Municipality, km 258 on the highway from Hermosillo to Yécora, October 5, 1995 *E. Pérez-Silva, T. Herrera, M. Esqueda, A. Armenta, A. Núñez, R. Rodríguez & R. Santos* (CESUES 2073).

Comments — For *B. pusilla,* we do not follow the species concept of Kreisel (1967), who characterizes this species by small basidiomes with a *Lycoperdon*-type capillitium and non-pedicellate spores, characters not seen in the recently examined material. Larsson et al. (2009) amply discuss the taxonomic,



Figs. 14–19. *Bovista oblongispora* var. *oblongispora*: 14. Spores under SEM. 15. Spores under OM ×1000. *Bovista pusilla*: 16. Spores under SEM. 17. Spores under OM ×1000. *Bovista sempervirentium*: 18. Spores. 19. Pitted capillitium. Scale bars = 1 μm.

ecological, and phylogenetic aspects of *B. pusilla* that were considered in the determination of the studied materials: finely warted spores of 4.5–5.5 μm, pedicels of 3–9 μm, heteromorphic capillitium, a temperate distribution, and an association with mosses. These characteristics totally match the studied material.

Following Kreisel's (1967) concept, *B. pusilla* has been cited from seven Mexican federative entities (Guzmán & Herrera 1969; 1973; Rodríguez & Herrera 1970; Urista et al. 1985; Esqueda et al. 1990; 1996; Pérez-Silva et al. 1994); but following the criteria of Larsson et al. (2009), this species is known only from the states of Mexico, Jalisco, and Sonora.

Worldwide, *B. pusilla* sensu Kreisel (1967) is widely distributed in Europe and America and sensu Larsson et al. (2009) is registered from the northern Europe region.

Bovista sempervirentium Kreisel, Beih. Nova Hedwigia 25: 107, 1967. Figs 18–19

Basidiome 10–20 mm in diameter, globose. Exoperidium formed by small furfuraceous verrucae, comprised of hyphal elements. Endoperidium pseudopapyraceous, ochre-brown in color. Gleba is olive brown. Subgleba compact.

Intermediate type capillitium, hyphae 4–5 µm, with small pores, without septa or pseudosepta. Paracapillitium absent. Spores 3.5–5 µm, globose, verruculose, with a short pedicel.

Ecology & distribution — Solitary, terricolous in *Abies* and *Pinus* forest, although Kreisel (1967) reported it for a *Quercus virginiana* forest.

Specimens examined: **MÉXICO. Distrito Federal:** Los Leones Desert, July 02, 1950 *T. Herrera* (MEXU 1438). **Estado de México:** El Carmen Hill, Chimalpa, October 28, 1956 *T. Herrera* & *O. Sánchez* (MEXU 1430).

Comments — The examined specimens match *B. sempervirentium* as described by Kreisel (1967): they have an intermediate type capillitium with small pores but without septa or pseudosepta, verruculose spores with a short pedicel, an exoperidium composed of hyphal elements, and a subgleba.

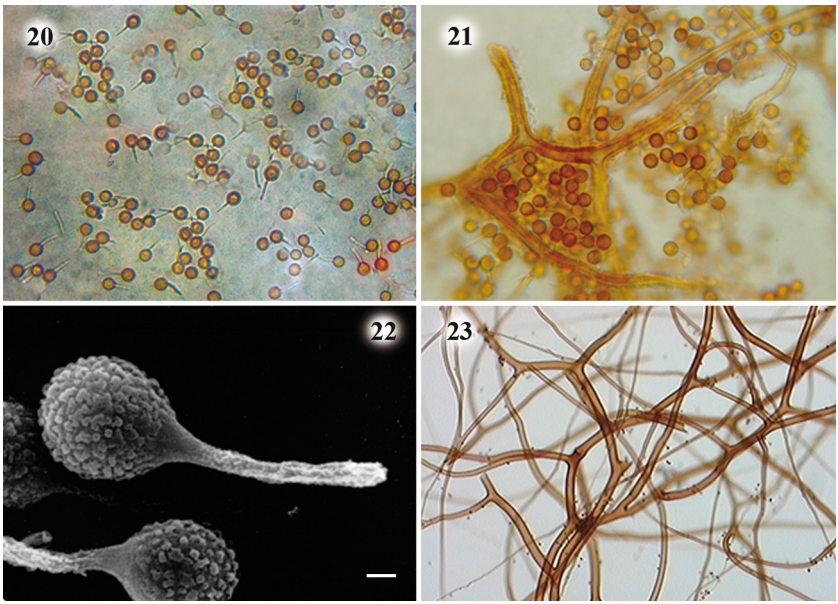
The species has been reported only for the United States of America (Kreisel 1967), thus this is the first record for Mexico, specifically for the Distrito Federal and the Estado de México.

Subgenus *Bovista*

Bovista brunnea Berk., Fl. Nov.-Zel. 2: 189, 1855. Figs 20–21

Specimens examined: **MÉXICO. Distrito Federal:** Los Leones Desert, July 10, 1949 *M. Ruiz-Oronoz & T. Herrera* (MEXU 1418). **Veracruz:** Las Vigas Municipality, Surroundings of El Volcancillo, SW of Encino Gacho, Xalapa-Perote road, November 30, 1991 *F. Tapia 922* (XAL).

Comments — This species is characterized by *Bovista* type capillitium with pores and no septa and a hyphal-vesiculate exostratum. An exoperidium was not observed in the examined material; only some amorphous structures could be seen, possibly owing to the weathering of the specimen. *Bovista brunnea* is placed in the *Globisporae* series, which also includes *B. echinella* Pat., *B. verrucosa* (G.H. Cunn.) G.H. Cunn., and *B. leucoderma. Bovista echinella* is distinguished by a hyphal exostratum and a thin papyraceous endoperidium, *B. verrucosa* has a distinctive mycelial cord, and *B. leucoderma* has a white exoperidium that forms small plates on the endoperidium and a capillitium with infrequent septa.



Figs S. 20–23. *Bovista brunnea*: 20. Spores under OM ×500. 21. Capillitium and spores ×600. *Bovista fusca*: 22. Spores. 23. Capillitium under OM ×100. Scale bars = 1 μm.

Herrera (1959) mistakenly cited *B. brunnea* for the Estado de México but later redetermined the collection as *B. dealbata* [≡ *B. leucoderma*] (Herrera 1964, Guzmán & Herrera 1969), and thus the *B. brunnea* record for the state must be discarded. The only authentic previous record from Mexico is from Veracruz (Calonge et al. 2004b).

Bovista fusca Lév., Ann. Sci. Nat., Bot., sér. 3, 5: 303, 1846. Figs 22–23

Representative specimens examined (total collections = 103): **México. Distrito Federal:** Monte Alegre, Ajusco Mountains, September 20, 1980 *E. Aguirre* (MEXU 17044). **Durango:** Pueblo Nuevo Municipality, Las Bayas Property, Los Otates stream, July 16, 2009 *S. Bautista* & *E. Aguirre* (MEXU 26301). **Guerrero:** Chichihualco Municipality, km 8.5 between El Carrizal and Atoyac, *M. Robledo 61* July 12, 1980, (FCME 986). **Hidalgo:** Piedras Voladas, Real del Monte, June 13, 1982 *E. Pérez-Silva* & *R. Hernández* (MEXU 17282). **Jalisco:** Ciudad Guzmán Municipality, Nevado de Colima Mountain foothills, El Floripondio, September 25, 1992 *V. Chaparro 3* (IBUG, MEXU 25378). **Estado de México:** Jalatlaco Municipality, km 13.5 on the Jalatlaco-El Ajusco Highway, August 4, 1986 *A. Calderón* & *E. Aguirre* (MEXU 21594). **Michoacán:** Mariposa Monarca Sanctuary, near Angangueo, February 5, 1981 *S. Acosta 584* (ENCB). **Morelos**: Zempoala Lagoons, July 27, 1985 *A. Calderón* (MEXU 19857). **Oaxaca:** 3 km SE of Plan de Guadalupe, La Cañada, June 13, 1991 *Pérez-Silva* et

al. (MEXU 22788). **Puebla:** Chignahuapan Municipality, Apizaco-Chignahuapan Highway, Cieneguilla Larga, July 13, 2000, *F. Tapia 2050* (XAL). **Tlaxcala:** San Salvador, November 13, 1983 *C. Martínez* (IZTA 2540). **Veracruz:** Rafael Lucio Municipality, Santa Bárbara Farm, 10 km NE of the Xalapa-La Joya Highway, July 8, 1998 *F. Ramírez-Guillén 100* (XAL).

Comments — This species is characterized macroscopically by a papyraceous shiny peridium, especially in mature specimens; on maturing the basidiomes separate easily from the substrate. Macroscopically it can be confused with *B. graveolens*, however the difference lies mainly in the shape of the pedicels. Some authors have confused *B. fusca* with *B. nigrescens* Pers. (Calonge et al. 2004b), although that species occurs only in Europe; Calonge et al. (2005) verified that the XAL specimens earlier identified as *B. nigrescens* represent instead *B. fusca*.

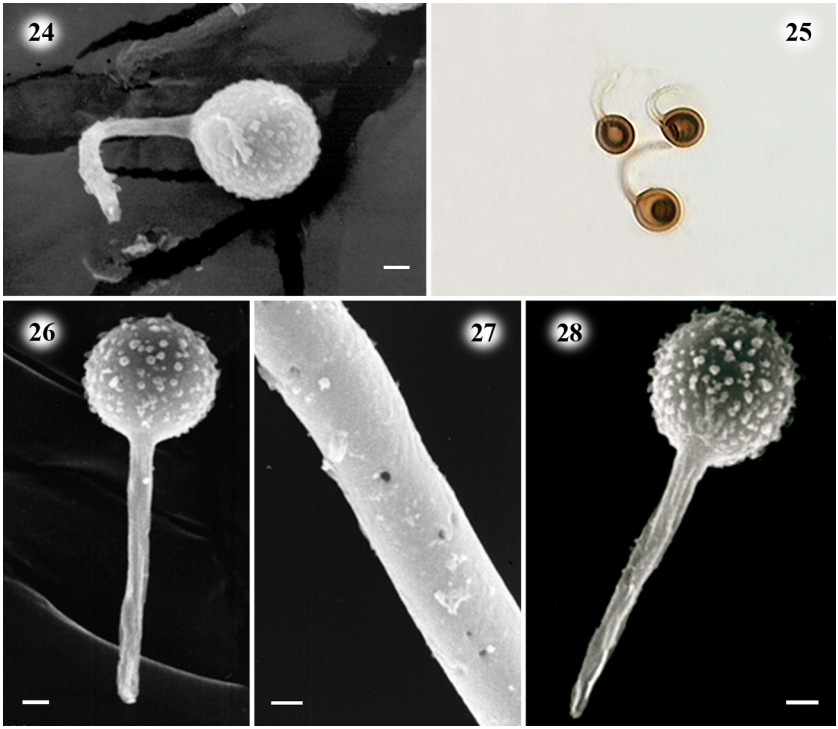
Observed in some of the examined specimens were clamp connections on brown dichotomously branching hyphae with thin walls and thin-walled septate ochraceous hyphae with projections shaped like small tubercles interspersed in the capillitium. Additionally, the pedicel surface appears smooth under the OM but rough and wrinkly with the SEM. It is notable that these details have not been reported in previous studies, although these are not diagnostic, with the exception of the pedicel, which is unique to *B. fusca*.

The taxonomy of *B. fusca* is complex and not very clear, because the material examined, particularly in the collections of young specimens, was easily confused with *Lycoperdon* basidiomes, given that they have a rigid granulose-squamulose peridium. As mentioned previously, *B. fusca* specimens are easily confused with other taxa precisely because our knowledge of this species is so scarce. Herrera (1959) described Mexican material as a new species, *B. ruizii*, which Kreisel (1967) synonymized with *B. fusca*.

The widely distributed *B. fusca* is very common in México's temperate forests and has been recorded for Aguascalientes (Pardavé 1991 [as *B. ruizii*]), Distrito Federal, Estado de México (Kreisel 1967), and Chihuahua (Moreno et al. 2010). This study extends its range to the states of Durango, Guerrero, Hidalgo, Jalisco, Michoacán, Morelos, Oaxaca, Puebla, Tlaxcala and Veracruz.

Bovista graveolens Schwalb, Lotos N. F. 13: 53, 1893. Figs 24–25

Specimens examined: **México. Estado de México:** La Marquesa-Tenango Highway, August 18, 1979 *E. Pérez-Silva* (MEXU 16052); Zinacantepec Municipality, km 17 Zultepec-Nevado de Toluca Highway near the town of Raíces, June 18, 1993 *A. Castellanos* (IZTA 2536). **Michoacán:** Zinapécuaro Municipality, Los Azufres long lagoon under forest protection, July 25, 1987 *Pompa-González 14* (FCME 13906). **Tlaxcala:** 2 km south of the La Malinche hostel, La Malinche Hill, July 19, 1987 *G. Mata 200* (XAL). **Veracruz:** La Joya, El Rodeo, February 18, 1985 *S. Chacón 3387 B* (XAL); Rafael Lucio Municipality, La Joya in front of the "La cabaña del chivo" restaurant, July 8, 1987 *F. Ramírez-Guillén 102* (XAL); Xico Municipality, eastern



Figs. 24–28. *Bovista graveolens*: 24. Spores under SEM. 25. Spores under OM ×1000. *Bovista leucoderma*: 26. Spores. 27. Pitted capillitium. *Bovista plumbea*: 28. Spore. Scale bars = 1 µm.

region of the Cofre de Perote mountain, Los Gallos, 15 km N of the El Rosario sugar refinery, May 15, 1995 *J. Rico 756* (XAL).

Comments — *Bovista graveolens* is characterized microscopically by the curved C-shaped pedicels on the majority of its spores that sometimes occur at the end of a widening corresponding to the basidium wall, although there are also spores with straight pedicels. The capillitium is very branched and the secondary hyphae are very long, compared with those of *B. fusca*. Although this species is easily confused with *B. fusca*, because its basidiomes are very similar, the differences become markedly evident under the microscope.

Bovista graveolens was known only for the state of Tlaxcala (Calonge et al. 2004b), but the present study broadens its distribution to include Estado de México, Michoacán, and Veracruz.

Bovista leucoderma Kreisel, Feddes Repert. 69: 203, 1964. Figs 26–27

Specimens examined: **México. Distrito Federal:** *S. González 97* (ENCB). **Hidalgo:** Loma Ancha, Marqués Dam, San Bartolo Socalpa, November 06, 1974

R. Cruz (ENCB); Omitlán de Juárez Municipality, Vicente Guerrero Ranch, ahead of the Real del Monte Mexico-Tampico Highway, short route km 115, July 05, 1986 *A. Calderón* et al. (MEXU 20142); Epazoyucan Peñas Largas Municipality, August 03, 1975 *M. Medina & I. García 1102* (ENCB); Zempoala Municipality, Tepa, November 20, 1976 *J. Baca del Moral* (ENCB); San Miguel Regla, August 16, 1980 *E. Pérez-Silva* (MEXU 17180). **Estado de México:** La Palma Hill, Salazar, October 20, 1957 *M. Ruiz-Oronoz* (MEXU 141); Between Chalco and Amecameca, September 05, 1965 *J. Álvarez* (MEXU 19864); km 39 Xochimilco-Oaxtepec Highway, August 24, 1980 *E. Fuentes* (MEXU 17098); San Pablo Teacalco, NE of Los Reyes, Mexico-Pachuca Highway, June 30, 1968 *J.L. Magaña 38-B* (ENCB); Tlamacas, foothills of Popocatépetl, August 31, 1958 *E. Pérez-Silva* (MEXU 889); Salazar, October 01, 1961 *Herrera, Zenteno* & *Riba* (MEXU 7805); October 19, 1969 *Herrera, Ulloa* & *Vázquez* (MEXU 6772); Purificación, NE of Texcoco, September 05, 1976 *G. Guzmán 16482* (ENCB); Tlalnepantla Municipality, Guadalupe Lake, September 15, 1968 *F. Martínez 61* (ENCB). **Puebla:** Tepeyahualco, May, 1999 *L. Mohedano 3* (XAL). **Veracruz:** Foothills of the Cofre de Perote mountain, October 30, 1982 *L. Guzmán-Dávalos 724* (ENCB).

Comments — *Bovista leucoderma* is mainly characterized by basidiomes with a white exoperidium that forms small plates in mature specimens. The *Bovista* type capillitium contains pores, pseudosepta and true septa.

This species has been cited for the states of Baja California (Ochoa 1993), Distrito Federal, Hidalgo, Puebla (Guzmán & Herrera 1973), and Estado de México (Kreisel 1967; Guzmán & Herrera 1973). Here it is reported for the first time for the state of Veracruz.

Bovista plumbea Pers., Ann. Bot. (Usteri) 15: 4, 1795. Fig 28

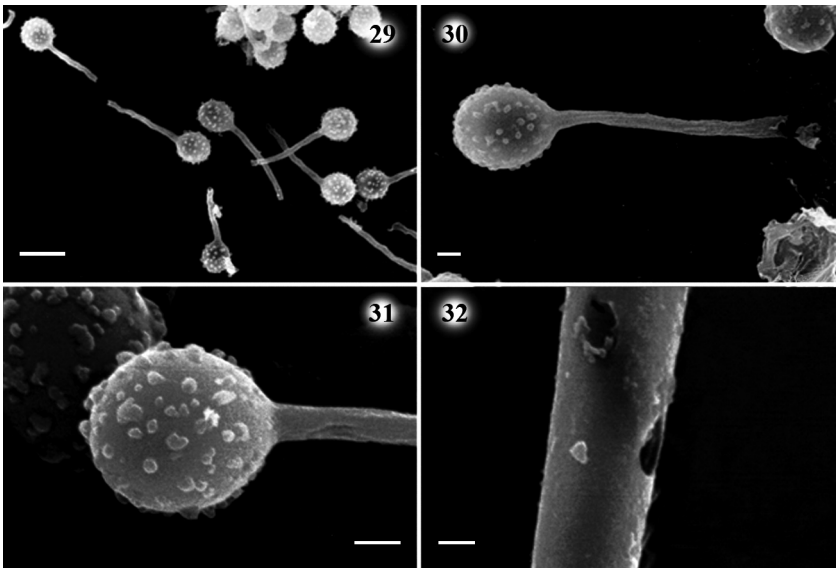
Specimens examined: **MÉXICO. Baja California:** Doña Petra Canyon, N of Ensenada, January, 1971 *S. Guzmán del Próo & S. de la Campa* (ENCB); El Junco, 15 km NE of Ensenada, February, 1983 *N. Ayala 46-B* (XAL); Vallecitos, San Telmo to Observatory of the UNAM road, San Pedro Mártir mountains, February 25, 1984 *G. Guzmán 24277-A* (XAL).

Comments — This species is easily recognized by its white exoperidium which, when removed, reveals the lead grey endoperidium.

In México, *B. plumbea* has been recorded only for Baja California (Ochoa & Moreno 1996, Ochoa et al. 2000); a previous report for Veracruz is rejected (Calonge et al. 2004b; Ochoa & Moreno 2006) as the cited specimen (L. Montoya-Bello 698 XAL) has been redetermined to *B. fusca*. Kreisel (1967) mentions that *B. plumbea* is distributed in northern New Zealand and over a vast region in Europe, Asia, and North America.

Bovista tomentosa (Vittad.) De Toni, Syll. Fung. 7: 97, 1888. Figs 29–32

Specimens examined: **MÉXICO. Baja California:** Turnoff at km 55 on the Ensenada-San Felipe Highway, km 15 road to the Hanson Lagoon, Juárez mountains, March 2, 1984 *Ayala 365*; *G. Guzmán 24328-A* (XAL). **Hidalgo:** Surroundings of San Gregorio, N side of Xihuingo Hill, July 26, 1963 *G. Guzmán 3875* (ENCB; MEXU 5548); Highway from Pachuca to Venados, turnoff to El Chico, Barranca Oriental, June



Figs. 29–32: *Bovista tomentosa:* 29–31. Spores. 32. Pitted capillitium. Scale bars: 29 = 5 µm; 30–32 = 1 µm.

24, 1973 *G. Guzmán 10874* (ENCB). **Estado de México**: Satélite City, June 29, 1982 *E. Pérez-Silva* (MEXU 22489); Zumpango Municipality, San Pablo Teacalco, June 30, 1968 *E. Quezada-Guzmán 10* (ENCB).

Comments — Specimens from the XAL herbarium identified as *B. minor* Morgan and *B. tomentosa* by Calonge et al. (2004b) were compared but no significant microscopic differences were found. Examination of an herbarium specimen from Belgium identified as *B. tomentosa* by Demoulin revealed that the XAL Mexican specimens cited above coincide both macro- and microscopically with the Belgian material.

Kreisel (1967) placed *B. tomentosa* (European) and *B. minor* (North American) in subg. *Globaria* sect. *Ovisporae* because of their ovoid spores and the *Bovista* type capillitium with pores. Microscopically, these two species are very similar, and Kreisel differentiated them based on their depth in the soil: *B. tomentosa* has one third of its basidiome immersed in the substrate and grows in arid dry open regions, while *B. minor* produces subhypogeous basidiomes with only the upper part above the soil and grows in humid regions in the shade. We believe that the relationship between basidiome and substrate is an ecological character lacking in taxonomic value. Because of the macro- and microscopic similarities between the two species, we suggest that they are conspecific, with *B. tomentosa* as the prior name.

Bovista tomentosa is characterized by the presence of mainly ovoid verrucose pedicellate spores and a *Bovista* type capillitium with pores. In some specimens both the primary and secondary hyphae have pores, while in others only the secondary hyphae have them.

Bovista tomentosa has been cited for the state of Baja California (Calonge et al. 2004b). This study extends its distribution range to Estado de México and Hidalgo.

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